Submitted by
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mtg

REPORT
to the
CONTRA COSTA COUNTY WATER AGENCY
on a
STUDY OF THE EFFECTS OF THE PROPOSED
FEDERAL SAN LUIS INTERCEPTOR DRAIN
and the
STATE SAN JOAQUIN VALLEY MASTER DRAIN

METCALF & EDDY
ENGINEERS
BOSTON - NEW YORK - PALO ALTO

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Whenever possible, we have estimated the cost in dollars to Contra Costa County of the effects of the drain. These estimates are necessarily approximate, and are dependent on a number of factors, foremost among which is the actual growth of the County, both in population and industry.

The writer is indebted to many members of the staff who worked under my supervision in the preparation of this report, in particular to Allen J. Burdoin and Dr. Perry L. McCarty. Dr. Clair N. Sawyer, our Director of Research, was also consulted on this project.

For a brief summary of the results of the study we refer you to the section titled "Summary and Conclusions." We trust this report will be of assistance to you in considering the problems with which it is concerned.

Respectfully submitted,

METCALF & EDDY

Rolf Eliassen

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Resident Partner

LIST OF TABLES

INTRODUCTION

The Sacramento River with a drainage area of 26,900 square miles, the San Joaquin River with a drainage area of 16,000 square miles, and 16,000 square miles of the Tulare Lake Basin which seldom contributes runoff, drain the Central Valley of California and come together in the Delta which extends from the vicinity of Pittsburg on the west to Sacramento on the north, Stockton on the east, and Tracy on the south. These two rivers unite at Collinsville, near the City of Pittsburg, and discharge their flows by way of Suisun, San Pablo and San Francisco Bays into the Pacific Ocean. The Delta is interlaced with 700 miles of interconnected channels, forming more than 50 separate islands, the majority of which are below sea level and are protected by levees. These islands form a rich agricultural area.

Contra Costa County is bounded on the east by the channels of the Delta, on the north by the San Joaquin River and by Honker and Suisun Bays and Carquinez Strait, and on the west by San Pablo and San Francisco Bays. The good quality of these waters constitutes a natural resource of great value to the residents of Contra Costa County and its preservation is a matter of vital concern to them. The availability of this water has been an important factor in the location of many large industries along the northern shore of Contra Costa County. This important industrial area has a great potential for future growth provided it can be assured of the continuation of an adequate water supply, and a means of disposal of its wastes.

Figure 1 is a map of Contra Costa County and its offshore waters, showing its relation to the Delta on the east and the San Francisco Bay area on the west and south.

Two major drainage facilities have been authorized for construction to convey future agricultural subsurface waste waters from the San Joaquin Valley. One is the San Luis Interceptor Drain, authorized for construction by the U. S. Bureau of Reclamation to carry wastes from the San Luis Division of the Central Valley Project. The other is the State of California's San Joaquin Valley Master Drain which would provide drainage disposal for other areas including the southern portion of the San Joaquin Valley. Since the authorization of this study, we have learned that the State Department of Water Resources and the U S Bureau of Reclamation have agreed to the construction of a combined drain to serve the entire Valley. Both agencies are cooperating in preliminary planning and estimates by means of a joint task force while negotiations proceed for putting the terms of the agreement into writing. The proposed point of discharge is into the San Joaquin River in the vicinity of the Antioch Bridge. Figure 2 is a map showing the approximate location of the drain as taken from Reference 31.

Considerable opposition to this proposal has developed, and the State now proposes to install monitoring equipment to determine the effects of the waste discharge on the river water Unofficial statements have been made to the effect that if these tests prove the need for it, the drain will be extended to a discharge point further to the west, presumably in the vicinity of Port Chicago. Whether such an extension could be made in time to prevent irreparable damage to the offshore waters of Contra Costa County is problematical. How such an extension would be financed has not been disclosed.

In studying the effects of the discharge of the drain, the California Water Plan is an important factor of an as yet undetermined magnitude. The method of transporting the water across the Delta and protecting its quality in the process is still being studied. If a physical or hydraulic barrier (32) scheme is adopted, the offshore water should remain suitable as a source of high quality municipal and industrial water at least during a substantial portion of the year unless adversely affected by the drain

In computing the changes in concentration of chemical constituents in the river caused by the drain, we have assumed that the present policy of a minimum calculated net outflow of 1500 cfs. from the Delta, exclusive of waste drainage flows from the San Joaquin Valley, would be maintained. Under these conditions the effect of the drain on the offshore waters as a source of water supply can be computed. On the other hand, if a peripheral canal or the Delta Waterways Control Plan is adopted, we understand that attempts to control the salinity in the San Joaquin River will be abandoned and it will no longer be suitable as a source of water supply except for cooling purposes. In this case, a substitute overland water supply would be made available to municipalities and industries in Contra Costa County. This water will undoubtedly cost the user more than water from the river. The extra cost in this case may logically be considered a result of the adoption of the California Water Plan by the State and to have no relation to the drain, except insofar as the need to find an economical point of discharge for the drain affects the decision on how to transport water across the Delta.

In the preparation of this report it has been necessary to rely heavily on previous studies of the Delta and Bay Areas. Reports of the State Department of Fish and Game, the U. S. Public Health Service, the Sanitary Engineering Research Laboratory of the University of California, and the State Department of Water Resources have been particularly helpful. The data in Bulletin 76 of the State Department of Water Resources and its various appendices was referred to quite extensively by the U. S. Public Health Service in the preparation of Reference 3, and was found by us to be a convenient source of information concerning river flows, salinity incursion, present and future recreational use of the Delta, and estimates of future water requirements. It has not of course been possible to check the accuracy of the figures obtained from these sources. It should not be implied from our use of these figures that we necessarily agree or disagree with any of the conclusions or recommendations in these reports.

TABLE 1

SAN LUIS DRAIN - ESTIMATED FLOWS***

Year	Acre Feet Per Year	Peak Flow Cfs*	Reference**
1968-73	10,000	25	1
1978	55,000	91.7	2
1993	240,000	400	1
2068	240,000	400	2

* Cfs = cubic feet per second

** Numbers refer to references listed in Table of References at end of report

*** Does not include any municipal or industrial waste.

State figures furthermore allow for a reduction in the drainage quantity per acre as the existing salts are leached from the soil, whereas the Bureau figures are based on a constant rate per acre.

The estimates make no allowance for municipal and industrial wastes, although plans are being made to accept such wastes provided they meet certain minimum requirements which are in the process of formulation. It is the opinion of State engineers that municipal wastes from the larger cities on the east side of the valley could more economically be disposed of as irrigation water after secondary treatment, but that the smaller municipalities on the west side of the valley might find it preferable to discharge directly to the drain. If this proves to be the case, the additional capacity required would be small, since the drainage from areas which would be irrigated with sewage effluent from the larger cities has already been included in the estimates of drainage based on acreage.

For the purpose of discussion in this report and as a basis for computation we have adopted the figures in the last two columns of Table 2 They lie between the estimate of the Bureau and the maximum estimate of the Department, but have no greater claim to accuracy than the estimates of either agency. The peak flows given in cfs. are based on a peak flow of 14 percent of the annual average occurring in the maximum month initially. This is reduced to 12 percent as the flows approach the capacity and assumes that the regulating reservoir will be in operation

There has been some consideration given to building a drain of lesser capacity initially and later enlarging it as the flows increase. We have been informed that this could be economically justified based on the flows estimated by the Bureau but not on the basis of the larger of the two estimates by the Department A final decision on this lies in the future.

TABLE 3

SAN LUIS DRAIN - ESTIMATED QUALITY OF WASTE WATERS*

Year	1968	1978	1993	2068
Constituent	Concentration in Parts Per Million			
Total dissolved solids**	7,000	4,200	5,100	3,000
Chlorides	700	420	510	300
Sulfates	3,800	2,170	2,650	1,300
Boron	15	15	15	15
Nitrogen	22.5	22.5	22.5	22.5

* From Reference 2

** In Reference 1, Alternative Solutions for Drainage, the initial concentration of total dissolved solids is estimated at 15,000 ppm initially, and the statement is made that this concentration is expected to decrease to 3,000 to 4,000 ppm after twenty to thirty years.

TABLE 5

COMBINED DRAIN - ESTIMATED QUALITY OF WASTE WATERS AT TERMINAL POINT*

Chemical Constituents	Initial Conditions in PPM	PPM after 50 Years of Operation
Total dissolved solids	5,800	2,500
Calcium	208	130
Magnesium	63	40
Sodium	2,400	738
Potassium	16	12
Bicarbonate	400	122
Sulfate	2,400	701
Chloride	2,150	957
Boron	10	3
Total Nitrogen	21.3	21.3
Phosphate	0.10	0.10
Phosphate & Organic Phosphate	0.14	0.14
Phenolic Material	0.001	0.001
Grease & Oil	0.7	0.7

*Estimate by State Department of Water Resources, dated May 7, 1964. Initial concentration assumes entire drain is built initially; hence, they do not allow for postponement of construction of the section south of Kettleman City.

TABLE 6

ESTIMATED QUALITY OF DRAINAGE WASTE WATERS
(Adopted as a basis for the studies in this report)

	San Luis Drain		Combined Drain	
	Year 1968	Year 1995	Year 1969 to Year 1975	Year 1995
Flow in Cfs.	25	400	75 - 250	900
Constituent	Concentration in Parts Per Million			
Total dissolved solids	15,000	4,000	5,500	4,000
Chlorides (Cl)	2,100	1,500	2,100	1,500
Sulfates (SO_4)	3,800	2,600	2,300	1,500
Boron (B)	10	6	10	6
Total Nitrogen (N)	21	21	21	21
Phosphates (PO_4)	0.14	0.14	0.14	0.14
	Concentration in Parts Per Billion			
Pesticides	3	3	3	3

RIVER FLOW AND EFFECT OF DRAIN ON RIVER QUALITY

River Flow - The flow in both the San Joaquin and Sacramento Rivers is tidal along the entire northern border of Contra Costa County and upstream therefrom and throughout the Delta for a considerable distance. Where river stages are influenced by tidal effects, daily flows cannot be obtained from records of river stages and consequently are not tabulated. River outflows from the Delta can be estimated by subtracting from the inflow to the Delta the amount of water exported from the Delta by the Contra Costa and Delta Mendota Canals and the consumptive use by irrigation within the Delta itself.

Average monthly outflows from the Delta are shown in Table 7. They are taken from the 20-year average estimate in Table 24 of Reference 4 which assumes present conditions prior to the operation of the California Water Plan. Releases from Folsom and Shasta Reservoirs are assumed to be regulated to maintain a minimum outflow of 1500 cfs. from the Delta, which we understand corresponds to present methods of operation by the Bureau of Reclamation. The original operating criterion of maintaining a minimum calculated net outflow from the Delta of 3300 cfs. for salinity repulsion has not been followed since the summer of 1957. The Bureau claims to have found that 1500 cfs. is sufficient to insure satisfactory quality water at the intakes of the Contra Costa and Delta Mendota Canals and has made this the criterion to be followed. Figure 3 is a monthly duration curve of the outflow from the Delta computed from the same data on which Table 7 is based. This curve shows that for 16 percent of the time, or almost two months in an average year, the outflow from the Delta is less than or equal to 1660 cfs. whereas Table 7, compiled on a calendar month basis gives 1550 cfs. for the lowest month, August, and 2440 cfs. for the second lowest month, July. An examination of the original table reveals that on the average, once in four years, the minimum outflow of 1500 cfs. will prevail throughout the three consecutive months of June, July, and August. Table 7 also includes an

TABLE 7

NET FRESHWATER OUTFLOW FROM
DELTA IN A THEORETICAL AVERAGE YEAR

Month	Total Net Outflow: Thousand Acre Feet (1)	Total Net Outflow: Cfs. (2)	San Joaquin River at Antioch Bridge Cfs. (3)
October	465	7,560	4,550
November	764	12,800	7,680
December	1,546	25,200	13,400
January	1,890	30,800	15,600
February	3,434	61,500	25,600
March	2,841	46,300	21,000
April	2,415	40,600	19,200
May	1,793	29,200	15,000
June	882	14,900	8,950
July	150	2,440	1,460
August	95	1,550	930
September	301	5,060	3,040

Note: Outflow figures derived assuming a minimum net outflow of 1500 cfs.

on the ebb tide would not return as far upstream on the second flood tide. At the proposed point of discharge, however, the water of the river will move upstream and downstream with the tides, receiving wastes continually as the water passes the outlet. If the water is assumed to move as a solid piston, and the average fresh water outflow in the San Joaquin River is assumed to be 1000 cfs. at the Antioch Bridge in the month of August, it would take 51 tidal cycles or 26-1/2 days for a piston having the length of a tidal oscillation to pass the point of discharge. The effect of this upstream and downstream oscillation should be to effect excellent mixing of the wastes with the river flow, provided suitable precautions are taken to disperse the wastes across the width of the river. It is therefore reasonable to assume when considering conditions downstream from the point of waste discharge that the wastes will be uniformly mixed with the steady fresh water outflow of the river and its admixture of salt water due to salinity incursion. The only effect of the tidal oscillations will be a time lag in attaining steady state conditions as the Delta outflow changes, and to diffuse a portion of the wastes upstream. The upstream diffusion can be estimated from salinity concentrations by the method of Ketchum (30).

Effect of Drain on River Quality - We have estimated and shown in the first column of Tables 8 to 13 present quality of the water in the river at the Antioch Bridge for the average year assuming outflows from the Delta as shown in Column 2 of Table 7. Chlorides were estimated from the outflow from the Delta using Plate 15 of Reference 4. Total dissolved solids, sulfates, and boron were estimated by determining relations between the concentrations of these substances and the concentration of chlorides from data in References 5, 6, 7, and 8. Figures for total nitrogen were obtained by a graphical analysis of the figures for nitrate and ammonia nitrogen reported in References 26, 27, and 28. The figure for pesticides

TABLE 9

ESTIMATED CONCENTRATION OF TOTAL DISSOLVED SOLIDS IN SAN JOAQUIN RIVER AT ANTIOCH BRIDGE - PARTS PER MILLION

		With San Luis Drain		With Combined Drain		
Month	Estimated Present Concentration	Initial Flow 25 cfs	Year 1995 Flow 400 cfs	Year 1969 Flow 75 cfs	Year 1975 Flow 250 cfs	Year 1995 Flow 900 cfs
October	265	345	565	350	535	880
November	160	210	350	210	330	560
December	160	190	270	190	260	400
January	160	180	260	190	240	370
February	160	170	220	180	210	290
March	160	180	230	180	220	320
April	160	180	240	180	230	330
May	160	190	260	190	250	380
June	160	200	325	200	305	510
July	2420	2620	2740	2560	2840	3000
August	3800	4060	3850	3910	4130	3890
September	700	815	1080	815	1060	1450

TABLE 11

ESTIMATED CONCENTRATION OF BORON IN SAN JOAQUIN RIVER AT ANTIOCH BRIDGE - PARTS PER MILLION

Month	Estimated Present Concentration	With San Luis Drain: Initial Flow 25 cfs	With San Luis Drain: Year 1995 Flow 400 cfs	With Combined Drain: Year 1969 Flow 75 cfs	With Combined Drain: Year 1975 Flow 250 cfs	With Combined Drain: Year 1995 Flow 900 cfs
October	.10	.15	.58	.26	.62	1.07
November	.09	.12	.38	.19	.41	.71
December	.09	.11	.26	.15	.28	.46
January	.09	.11	.24	.14	.25	.42
February	.09	.10	.18	.12	.19	.29
March	.09	.10	.20	.13	.21	.33
April	.09	.10	.21	.13	.22	.36
May	.09	.11	.25	.14	.26	.43
June	.09	.12	.34	.17	.36	.63
July	.34	.49	1.49	.78	1.67	2.41
August	.49	.71	2.01	1.12	2.32	3.03
September	.15	.23	.82	.38	.89	1.47

TABLE 13

ESTIMATED CONCENTRATION OF PESTICIDES IN SAN JOAQUIN RIVER

AT ANTIOCH BRIDGE - PARTS PER BILLION

		With San Luis Drain		With Combined Drain		
Month	Estimated Present Concentration	Initial Flow 25 cfs	Year 1995 Flow 400 cfs	Year 1969 Flow 75 cfs	Year 1975 Flow 250 cfs	Year 1995 Flow 900 cfs
October	0.20	0.22	0.43	0.25	0.35	0.66
November	0.20	0.21	0.34	0.23	0.29	0.49
December	0.20	0.21	0.28	0.22	0.25	0.38
January	0.20	0.20	0.27	0.21	0.24	0.35
February	0.20	0.20	0.24	0.21	0.23	0.29
March	0.20	0.20	0.25	0.21	0.23	0.32
April	0.20	0.20	0.26	0.21	0.24	0.33
May	0.20	0.20	0.27	0.21	0.25	0.36
June	0.20	0.21	0.32	0.22	0.28	0.46
July	0.20	0.24	0.77	0.33	0.59	1.22
August	0.20	0.27	0.97	0.39	0.74	1.49
September	0.20	0.22	0.52	0.27	0.41	0.83

increased salinity, will be reduced by approximately 50 percent by the time the wastes reach Port Chicago. This is due mainly to additional dilution from the joining of the Sacramento and San Joaquin Rivers. This reduction from the values shown in Tables 8 to 13 will be the same whether the drain discharges at Antioch Bridge or at Port Chicago. However, if the wastes are discharged at Port Chicago, we estimate that the increase in concentration of pollution at the Antioch Bridge will vary from 0 to 12 percent of the increase in the estimated values over the present values shown in Tables 8 to 13.

In estimating the effect of the wastes on the quality of the river water, we have used the method of Ketchum (30) which utilizes the salinity of the river as a measure of the effect of sea water intrusion on the dilution at the point of discharge, and the variation in salinity upstream and downstream from the point of discharge as a measure of the effect of tidal diffusion.

TABLE 14

PROJECTED DELTA RECREATIONAL DEMAND

(Recreation days per year in thousands -- after Reference 10)

Residence of Recreationist	Year 1960	Year 1980	Year 2000	Year 2020	Percent of Year 2020 Demand
Contra Costa County	606	1278	2317	3509	25.3
San Joaquin County	756	1416	2440	3675	26.4
Solano County	78	166	702	2005	14.4
Sacramento County	297	588	972	1339	9.7
Other Bay Area Counties	829	1327	1824	2285	16.5
Elsewhere in California	214	400	653	1065	7.7
Totals	2,780	5,175	8,908	13,878	100.0

for striped bass lies in the San Joaquin River above the Pittsburg and Antioch area, and extends up to Stockton. The small fry are found in greatest abundance in Honker, Grizzly and Suisun Bays, and in the main channels of the Sacramento and San Joaquin Rivers in the Delta. Thus, this valuable sport fishery and the recreation it supports is quite dependent on good water quality in the San Joaquin River and various bays in the vicinity of Contra Costa County.

Waterfowl hunting is another recreational activity which is dependent upon the San Francisco Bay system. The Bay Area consistently provides about 25 percent of the state-wide duck total, and 5 to 10 percent of the geese (9). "Of the nine Bay Counties, Solano County with the Suisun marshes consistently harbors the most birds, followed by Contra Costa and Alameda Counties. The best breeding area presently is the Suisun marshes, although the marshes north of San Pablo Bay are used to some extent." These areas are downstream from the proposed San Joaquin Drain discharge at the Antioch Bridge or Port Chicago and could possibly be affected by this discharge.

Table 16 is a summary of the estimated annual value of the fishery and waterfowl resources in the San Francisco Bay Area and the Delta as given by Skinner (9). Although these figures pertain to the resources in the whole Bay Area, the major portion of these resources are affected by the water quality in the Delta and the Bay Area immediately downstream from the Delta. Table 17 shows the estimated capital investment by various groups in the fish and wildlife resources in the San Francisco Bay Area. This totals about $61,000,000.

Another estimate of the value of the recreational facilities in the Delta may be obtained from the number of recreation days listed in Table 14. Based on the gross expenditure method, the cost of an angler day has been estimated to vary between $9 and $18 per day (9) (16). Waterfowl

TABLE 17

CAPITAL INVESTMENT IN FISH AND WILDLIFE RESOURCES IN SAN FRANCISCO BAY AND DELTA AREA

(After Skinner (9))

Group Investing	Capital Outlay and Investment
Private Commercial Fishing Interests	$25,000,000
Private Sportfishing Interests	5,000,000
Private Waterfowl Club Lands	15,000,000
Governmental Agencies	16,300,000
Total Investment	$61,300,000

TABLE 18

PROJECTED ECONOMIC VALUE OF RECREATION IN THE DELTA AREA

Residence of Recreationist	Year 1960	Year 1980	Year 2000	Year 2020
Contra Costa County	$6,060,000	$12,780,000	$23,170,000	$35,090,000
Other Bay Area Counties	19,600,000	34,970,000	59,380,000	93,040,000
Elsewhere in California	2,140,000	4,000,000	6,530,000	10,650,000
Total	$27,800,000	$51,750,000	$89,080,000	$138,780,000

Salton Sea is silt or mud, with a mixture of snail and barnacle shells. The bottom has an organic mat above the silt, consisting mainly of settled plankton organisms, and near shore, blue-green algae.

The concentrations of nitrogen which will occur in the San Joaquin River as a result of the discharge of the drain at the Antioch Bridge are shown in Table 12 and are much above those which can cause the above problems. In fact, a study of the table reveals that concentrations of nitrogen are so great that serious detrimental effects may be experienced by 1975. It has been reported that phytoplankton (algae) concentrations in the Suisun Bay area are presently consistently higher than in most other areas of the Bay system (14). In addition, extensive "blooms" have occurred in Suisun Bay and the lower San Joaquin River which depleted essentially all of the available nitrogen in the water. Additional nutrients would be expected to allow even greater growths of phytoplankton.

The fish which are presently abundant in the Bay and Delta and are largely responsible for the current sport fishing industry are quite sensitive to fluctuations in oxygen levels and require relatively clean rivers for spawning and for life. They pass up through the lower Delta area for spawning, and the small fry pass back through this area on their way to the sea. Thus, the anadromous sport fishery in the whole Bay Area is to a large extent dependent upon a good quality water in the lower Delta area.

Waterfowl are also indirectly dependent upon a good water quality. Too extensive stands of tules and cattails which could result from additional plant nutrients may adversely affect nesting. Also, the normal healthy aquatic vegetation and animal organisms upon which waterfowl feed become suppressed under polluted conditions and eventually are succeeded by forms not usable (9). Continuation of the sport of waterfowl hunting depends upon the maintenance of a suitable habitat for them.

TABLE 19

COMPARATIVE TOXICITY OF CHLORINATED HYDROCARBON INSECTICIDES TO DIFFERENT SPECIES OF FISH IN SOFT WATER

(From Henderson, Pickering and Tarzwell, 1959 (19))

Insecticide	96-Hour TL_m (Median Tolerance Limit) ppb. active ingredient			
	Fatheads	Bluegills	Goldfish	Guppies
Aldrin	33.0	13.0	28.0	33.0
Dieldrin	16.0	7.9	37.0	22.0
Endrin	1.0	0.60	1.9	1.5
Chlordane	52.0	22.0	82.0	190.0
Heptachlor	94.0	19.0	230.0	107.0
Toxaphene	7.5	3.5	5.6	20.0
DDT	32.0	16.0	27.0	43.0
Methoxychlor	64.0	62.0	56.0	120.0
Lindane	62.0	77.0	152.0	138.0
BHC	2300.0	790.0	2300.0	2170.0

frequently are concentrated in aquatic life to levels well over the tolerance limits set by the U. S. Food and Drug Administration for pesticide residuals on food crops. Such tolerance limits range from less than 1 part per million for pesticides such as aldrin, chlordane, dieldrin, and endrin, up to 7 parts per million for DDT.

Many examples of danger from the concentration of pesticides in aquatic life can be cited. When the chlorinated hydrocarbon, DDD, was applied to Clear Lake, California, (2) in concentrations of about 0.02 parts per million, it became concentrated in the plankton and fish. The plankton analyzed contained 5 parts per million of DDD and the fish contained in the tens to hundreds of parts per million in the edible flesh or hundreds to thousands of parts per million in their fat. Grebes which fed on these fish died and were found to contain up to 38 parts per million of DDD in their flesh and up to 656 parts per million in their fat.

In Big Bear Lake, California, 0.20 parts per million of toxaphene was applied to control rough fish so the lake could be stocked with trout. The toxaphene concentrated to 73 parts per million in the plankton, 200 parts per million in goldfish, and 1,700 parts per million in the fat of pelicans which were found dead in the area. It was a year before trout could be successfully started in this lake, after which they concentrated the remaining toxaphene to levels as high as 3 parts per million in their flesh. A similar experience was observed at Clayton Lake, New Mexico (21), where three applications to give a total concentration of 0.05 parts per million were made to control rough fish. The toxaphene concentration in the lake water decreased rapidly after each application. However, the lake was still toxic to fish 9 months after treatment, although the concentration of toxaphene in the water was then only 0.001 parts per million.

Other aquatic life besides fish may be affected by very low pesticide levels. Oysters exposed to 0.01 parts per million of DDT for 1-week were portion of the valuable resources of the Bay Area cannot be ignored (9), and should serve as a warning that future alterations should be made cautiously and only after sufficient investigation. The changes which are created by pollution are usually subtle and occur slowly over extended periods of time. In the case of problems resulting from excessive nutrient concentration, the deterioration which results is often not reversible, and previous conditions may not return, even after corrective measures are taken. Thus, such a condition should be prevented before it develops.

The engineers of the State Department of Water Resources are aware that a potential hazard exists due to nutrients in the drain. They are contemplating building one or more experimental ponds to serve as pilot plants. The plan, as we understand it, is to grow algae in ponds, and then to harvest the algae, in this way removing nitrogen from the drain. In our opinion, the prospects of an economical solution of this problem are not bright. Even if a successful method of harvesting algae should be developed, the nitrogen-phosphorus ratio in the drain is so low in phosphorus that significant quantities of nitrogen would pass through the ponds to the river where ample phosphorous already exists to combine with nitrogen and support large algal blooms, unless phosphates were added to the drain in the right proportions, which would be very expensive.

There is no indication at the present time that lack of success in the above program will deter the State from constructing the drain and depending on their proposed monitoring system to give warning in time so that the drain can be extended to the west. In our opinion, it would be more desirable to make certain of consequences before finally selecting a point of discharge for the drain. An interim solution such as one of the plans considered in Reference 1 would provide time for additional studies to be made. Because Table 2 shows that the flows will increase much faster

EFFECT OF DRAIN ON ASSIMILATIVE CAPACITY OF RECEIVING WATERS

Assimilative Capacity - Rivers and estuaries have only a limited capacity to assimilate oxygen demanding wastes which may be discharged into them. This capacity varies with the temperature of the water, and the volume and quality of fresh water flow. If this capacity is exceeded, extensive damage to aesthetic values, recreation and aquatic life can result.

At present, the San Joaquin River near Contra Costa County is not overloaded and still has additional assimilative capacity for a future increased waste load. However, because of the large municipal and industrial expansion expected in this area, the capacity will eventually be exceeded unless extensive treatment of these future wastes is provided. If additional waste loads from other areas are added to the San Joaquin River, its assimilative capacity will be reached sooner, and a greater degree of treatment of municipal and industrial wastes will be required. Such an addition of wastes from the drain will thus result in a direct economic loss to communities and industries located on the San Joaquin River downstream from the point of discharge.

For the past four years, the Sanitary Engineering Research Laboratory of the University of California has been conducting for the State Water Quality Control Board a comprehensive study of conditions in San Francisco Bay including the Suisun Bay-Lower San Joaquin River Area. Data collected from October 1960 to May 1963 have been published in a series of reports (26) (27) (28). We have studied these reports and have analyzed the data having to do with dissolved oxygen and BOD loadings. Eighteen cruises were made in the three years during which several samples were taken for analysis at each of ten different stations from Carquinez Strait to the Antioch Bridge. These studies have enabled us to develop a method of estimating the assimilative capacity of Suisun Bay. The

TABLE 21

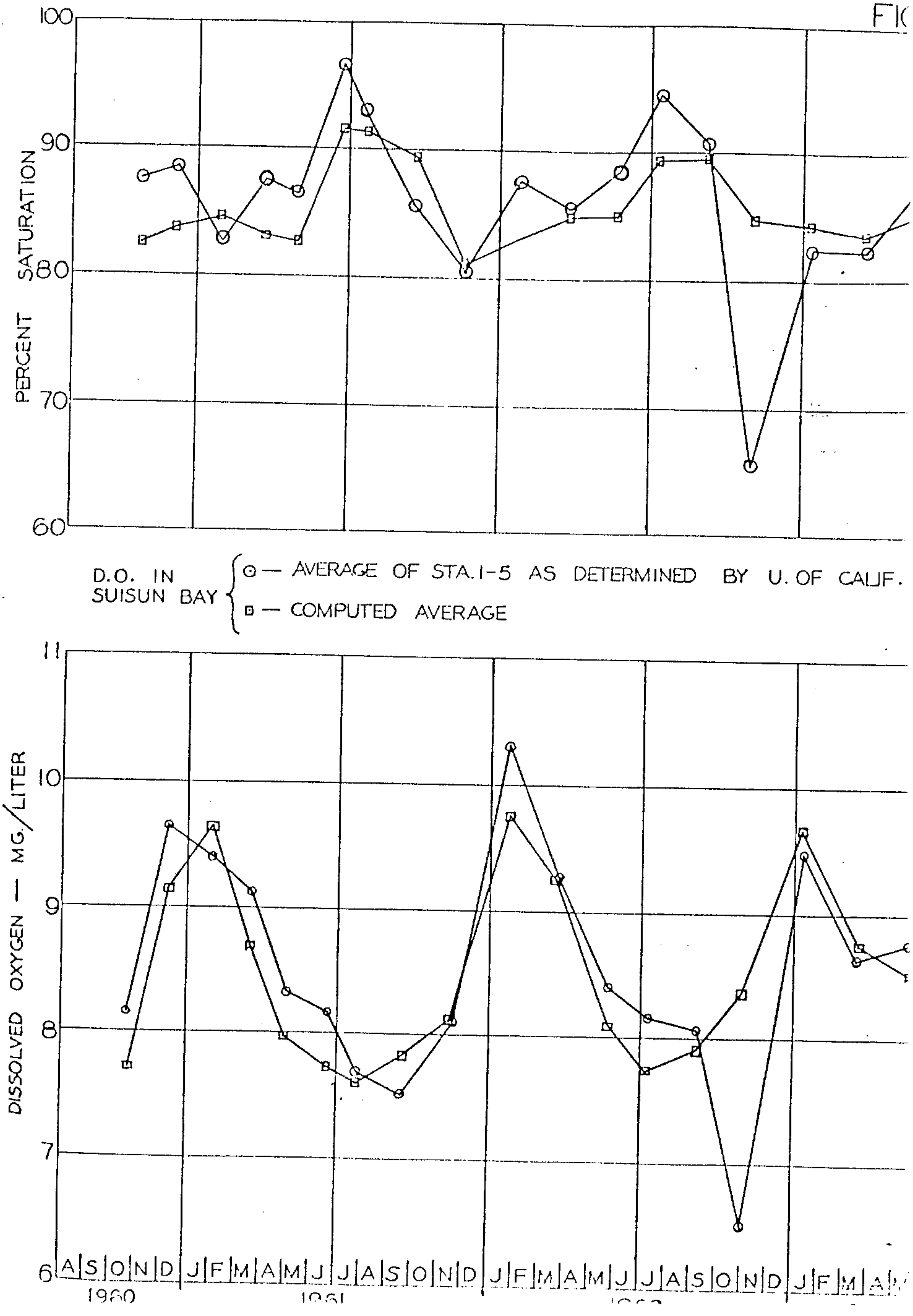
ESTIMATED PROJECTED

MUNICIPAL AND INDUSTRIAL WASTE LOAD TRIBUTARY

TO SUISUN BAY AND THE SAN JOAQUIN RIVER

5 Day BOD in Lbs. per Day

Year	1960	1980	2000	2020
Contra Costa County				
Municipal Wastes	30,300	59,000	130,000	259,000
Industrial Wastes	133,000	241,500	481,500	788,000
Total	163,300	300,500	611,500	1,047,000
Solano County				
Municipal Wastes	8,000	24,200	50,500	165,000
Industrial Wastes	13,400	89,400	189,000	625,000
Total	21,400	113,600	239,500	790,000
Total Raw Wastes Load, both Counties	184,700	414,100	851,000	1,837,000
Reduction by Minimum Treatment	18,200	50,100	131,000	357,000
Estimated Load	166,500	364,000	720,000	1,480,000



FI
PERCENT SATURATION
100
90
80
70
60
D.O. IN SUISUN BAY
— AVERAGE OF STA. 1-5 AS DETERMINED BY U. OF CALIF.
— COMPUTED AVERAGE
DISSOLVED OXYGEN — MG./LITER
11
10
9
8
7
6
A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
1960
1961

of the river and bay waters for the development of algae as noted in the previous section. Such growths can reasonably be expected to increase the spread between maximum and minimum dissolved oxygen values, and in this way reduce the pollution load that can be assimilated if a minimum DO concentration of 5 mg/l is maintained as required for salmon. This would be a daily or steady state effect during the summer months, its intensity varying gradually with the concentration of algae.

A second effect, which may be a seasonal effect as contrasted to a steady state effect, would be superimposed on the first effect. This would be the gradual development of algal blooms followed by their gradual death and decay. During normal growth and death of equal numbers of algae, we would not expect any net absorption of oxygen. However, during periods when death and decay predominate there would be a net demand for oxygen.

A third effect which may be expected to occur, is that algae will grow in the open drain and be discharged to the river. The eventual death and decay of these algal growths will constitute a net oxygen demand on the receiving waters which can be estimated. The growth of algae in the drain will be smaller than estimated by the U. S. Public Health Service (14) (35) because of the low concentration of phosphates in the drain (Table 6). We have assumed that the minimum phosphorus-nitrogen ratio would be about 1 to 15 or one-third of the optimum. On this basis, less than 5 percent of the nitrogen in the drain would be converted to algae in the drain. The balance would be discharged to the river where large amounts of phosphorus are available for additional growth of algae in Suisun Bay. These would have the first two effects noted above.

With the future growth of the area additional quantities of nitrogen and phosphorus will be discharged to the offshore waters in municipal and industrial wastes. Ample phosphorus is available in the above figures, a conservative estimate of the lost value of assimilative capacity due to the drain would be from $1,500,000 per year in 1975 to $2,300,000 in 1995.

Sometime shortly after the year 2000, complete treatment of municipal and industrial wastes discharged to the river and bay will be required to meet the assimilative capacity unless satisfactory and economical methods of reducing the effect of nutrients are developed in the meantime. This would hold true if the drain is not built, but with the drain, complete treatment will be required sooner. Unless methods of alleviating the effects of nutrients are developed, their effect on the assimilative capacity may establish an upper limit of industrial and municipal growth of Contra Costa County, which would be lower if the drain discharges at Antioch Bridge or Port Chicago than if it continued to the ocean. Since the effects of pollution in any part of the San Francisco Bay system are transmitted by tidal action throughout the whole area, a study should be undertaken of a comprehensive plan for the discharge of wastes from the entire Bay Area, and including the discharge from the combined drain. All users of the drain, including the State and the Federal Government should contribute their share of the cost based on the quantity and quality of their wastes.

In computing the cost of waste treatment to compensate for the loss of assimilative capacity, the effect of the drain on the assimilative capacity of San Pablo Bay has not been considered. The discharge of nutrients from the drain through Carquinez Strait would have a detrimental effect on the assimilative capacity of San Pablo Bay. To compensate for this, greater removals of BOD from industrial and municipal wastes discharged from Western Contra Costa County to San Pablo Bay would be required. The cost of this additional treatment in this area of the County due to the effect of the drain is not included in the above cost figures as no estimates have been made on which they could be based.

TABLE 22

PROJECTED DEVELOPED INDUSTRIAL ACREAGE
FOR CONTRA COSTA COUNTY EAST
OF MALLARD SLOUGH IN ACRES

Year	Developed Industrial Acreage (23)
1960	1,260
1970	2,260
1980	3,600
1990	5,240
2000	7,010
2010	8,920
2020	10,750

recirculated cooling purposes. The change in water quality in the river system due to the discharge from the proposed drain snould have no significant effect on the once-through use; however, some additional water conditioning costs will be incurred by industries which employ recirculating systems. The discnarge from the drain will affect the river system as a source of supply for high-quality water.

Table 24 lists projected high and low quality water requirements based on estimates by the Department of Water Resources (23). Most of the future industrial expansion with a significant water requirement can be expected to occur along the San Joaquin and Sacramento Rivers because of readily available water for cooling. Because of the economic advantage of using the river water to satisfy the high-quality water requirements, also, most of these industries can be expected to have a dual system of supply similar to that of many of the present water using industries.

The quality of water required by industries varies from industry to industry. In some cases the special requirements of an industry cannot be met even by water which may be entirely satisfactory for municipal usage. In other cases, the requirements are less stringent. In general, however industries have the same requirements for a clear, attractive water, free from odors, turbidity, and corrosive tendencies as do municipalities. In general, it is desirable to have high-quality water with chloride concentration less than 100 parts per million and total dissolved solids concentrations less than 400 parts per million. It was estimated that tne average penalty costs of chlorides in excess of 100 ppm to industrial users of high-quality water in Contra Costa Count was $0.281 per acre-foot of water per part per million of excessive chlorides (15). This was based on penalty costs to industries receiving water with excessive chlorides from the Contra Costa Canal.

With an available dual system for high-quality water, industries can obtain water either directly from the river or from the Contra Costa Canal, depending upon the water quality and relative cost of each supply. The most economical source of supply when quality is suitable is the river. The Department of Water Resources has prepared a series of curves which indicate the cost of river water as related to distance of the industry from the supply, the quantity of water being pumped, and the relative portion of the time the river water is used (23). In general, the water is more expensive the farther the industry lies from the source, the smaller its rate of demand, and the smaller the percentage of time the water is used. Since these variables will be different for each industry, the cost of using the river water will likewise vary considerably. However, by making certain assumptions, an average cost of river water to industry can be obtained which should permit making approximate cost computations.

The majority of industrial land lies within one mile of the San Joaquin-Sacramento Rivers, and practically all the land lies within two miles. It is estimated that the industries will have to pump river water an average distance of 4000 feet or approximately three-fourths of a mile. The quantity of water pumped by different industries also varies considerably. About one-half of the water is used by a few large-water consumers while the rest is used by many industries with a small demand. It is estimated that the average industry will use 1000 acre-feet per year, or approximately 620 gpm. Using these figures, the charts prepared by the Department of Water Resources indicate river water would cost \$4.40, \$5.80, and \$8.60 per acre-foot if this water were of proper quality 100, 60, and 40 percent of the time, respectively.

Water from the Contra Costa Canal is available at the canal at a cost of \$11.00 per acre-foot. Cost of transmission of the plant site would have to be added to this figure. In general, the canal lies roughly two miles from the river system, and at an elevation of about 110 to 120 feet above the river. Hence,

TABLE 25

ESTIMATED COST OF WATER TO INDUSTRY AS

RELATED TO SOURCE OF SUPPLY

Percent Usage of Water		Cost of Water per Acre-Foot		
From River	From Contra Costa Canal	From River	From Contra Costa Canal	Annual Average
100	0	$4.40	-	$4.40
60	40	5.80	18.50	10.88
40	60	8.60	16.00	13.04
0	100	-	14.00	14.00

TABLE 27

ESTIMATED ANNUAL INCREASE IN INDUSTRIAL HIGH-QUALITY WATER COST RESULTING FROM AGRICULTURAL DRAINAGE DISCHARGE AT ANTIOCH BRIDGE

	Industrial High-Quality Water Requirement	Average Increase in Water Cost Due to Excessive Chlorides from Agricultural Drain	
Date	Acre-Feet/Year	Per Acre-Foot	Total Increase
1969	66,000	$0.30	$ 19,800
1975	96,000	1.26	121,000
1995	236,000	2.00	472,000

EFFECT OF DRAIN ON MUNICIPAL WATER SUPPLIES

Municipal water in Contra Costa County is furnished by various water supplying agencies. These include the East Bay Municipal Utility District, Contra Costa County Water District, together with Oakley County Water District, and the Cities of Pittsburg and Antioch. The primary water sources available to the latter agencies, excepting EBMUD, are the San Joaquin River and the Contra Costa Canal. EBMUD derives their supply from the Mokelumne River by means of an overland conveyance system. Precipitation is of some importance, especially to agriculture, however, most of the water falls when it is least needed. Minor use is made of ground water by the Contra Costa County Water District in their Treated Water Division.

The western portion of Contra Costa County receives municipal water from the East Bay Municipal Utility District, which diverts water from the Mokelumne River Basin in the Sierras. The Sacramento-San Joaquin River system is the primary source of surface water for most other areas in Contra Costa County. A good portion of the surface water is obtained from the various river channels and sloughs lying upstream from the discharge of the proposed drain at Antioch Bridge. However, two important sources of municipal supply are downstream from the point of discharge and may be affected by quality changes in the water which will result.

One municipal supply which may be affected by the proposed drain is that of the City of Antioch. This city obtains its water supply from two sources: the San Joaquin River and the Contra Costa Canal. The river supply is used when it is acceptable by California Department of Public Health Standards, or when the quality is better than the quality in the Contra Costa Canal.

Estimates of future population growth and municipal water requirements for Contra Costa County are shown in Tables 28 and 29. The estimated population growth for the County is based on values reported by the California Department of Water Resources (23). The maximum rate of population growth is expected to occur in the areas of Contra Costa County which are adjacent to the Delta and Suisun Bay and could possibly make use of these as sources of raw water supply. This area is expected to grow from a present population of 162,000 to 1,193,000 in 2020 based on estimates by the U. S. Public Health Service (3). A similar rate of growth for this area was estimated by the California Department of Water Resources (23)

Projected municipal water requirements for Contra Costa County are shown in Table 29. The requirements for the whole county were based on the population estimates given in Table 28 and rates of water consumption increasing from a present 135 gallons to a 2020 estimate of 155 gallons per capita per day, as projected by the U. S. Public Health Service (3). These estimates were somewhat lower than estimates by the California Department of Water Resources, which estimated a consumption of 200 gallons per capita per day for the same area in 2020.

Also shown in Table 29 are estimates of present and future municipal water requirements supplied by the TWD and the City of Antioch, the two agencies which presently use water which may be affected by the discharge of the drain. The estimates for TWD were prepared by James M. Montgomery, Consulting Engineers (24). The future values shown are high with respect to the future municipal requirements for the whole county, but roughly parallel the expected population growth for the particular area considered, as indicated in Table 28. It should be noted that the water requirements for the TWD include some usage of treated water by industrial, as well as municipal users. This industrial usage ranges from a present value of about 3,000 acre-feet to an

TABLE 29

PROJECTED MUNICIPAL WATER REQUIREMENTS

CONTRA COSTA COUNTY

Acre-Feet per Year

Year	Total for County (3) (23)	Treated Water Division of CCC Water District (24)	City of Antioch (23)
1960	60, 300	15, 100	2, 900
1970	89, 000	25, 000	4, 600
1980	124, 500	44, 000	6, 800
1990	168, 500	65, 000	9, 400
2000	214, 000	90, 000	12, 400
2010	261, 000	116, 000	15, 800
2020	305, 000	134, 000	19, 800

TABLE 30

SUMMARY OF A PORTION OF THE

U. S. PUBLIC HEALTH SERVICE DRINKING WATER STANDARDS

Substance	Recommended Limits
Chlorides	250 ppm
Sulfates	250 ppm
Total dissolved solids	500 ppm
Nitrates (as N)	10 ppm
Carbon Chloroform extract	0.2 ppm

TABLE 31

ESTIMATED ANNUAL INCREASE IN MUNICIPAL WATER COSTS

RESULTING FROM DISCHARGE OF THE COMBINED DRAIN AT ANTIOCH BRIDGE

Municipal Water User Affected	Year	Projected Water Usage Acre-Feet	Increased Water Cost per Acre-Feet	Estimated Total Annual Increase in Water Cost
City of Antioch	1969	4,450	$0.30	$1,300
	1975	5,600	1.52	8,500
	1995	10,900	2.52	27,500
Treated Water Division Contra Costa County Water Dist.	1969	23,500	0.10	2,300
	1975	33,000	0.16	5,300
	1995	77,000	0.30	23,000

SUMMARY AND CONCLUSIONS

We present below a brief summary of this report of our studies and conclusions on the effect of the drain on the offshore waters of Contra Costa County. For greater detail reference should be made to previous sections of this report.

1. The State of California and the Federal Government are cooperating in studies for a combined drain, and it is reasonable to conclude that one combined drain will be built instead of two drains.

2. The proposed point of discharge of the combined drain is in the vicinity of the Antioch Bridge. Discharge is expected to begin in 1969 at a rate of 75 cfs., increase rapidly to 250 cfs. by 1975 and to 900 cfs. by 1995.

3. Serious deterioration of the quality of the offshore water can be expected by 1975, and conditions will gradually become worse until 1995. Some effects will be noticeable in 1969. Tables showing the effect of the discharge of the drain on the quality of the river at Antioch are contained in the report. These are based on the present quantity and quality of the receiving water at Antioch.

4. Aquatic life and recreational use of the offshore waters could be seriously affected by the discharge of nutrients and pesticides from the drain. Nutrients are expected to have a greater effect than pesticides. Laboratory studies of the

decrease of 70,000 lbs. per day of five-day BOD in the assimilative capacity of the river and Suisun Bay. The additional BOD load and reduction in assimilative capacity will have to be compensated for by more intensive treatment of municipal and industrial wastes. A conservative estimate of the cost of the additional treatment required varies from $1,500,000 per year in 1975 to $2,300,000 per year in 1995.

Sometime shortly after the year 2000, it may be impossible due to the combined effect of BOD and nutrients to reduce the projected future municipal and industrial waste load to the assimilative capacity of the receiving waters. An appreciable quantity of nutrients are contained in municipal and industrial wastes, which could have the same effect if the drain is not built. With the drain the effect will be felt sooner, and at a lesser degree of municipal and industrial development. The result could be to set a limit to the growth of Contra Costa County.

6. The discharge of the drain at the Antioch Bridge will cause deterioration of the quality of the offshore water both at Antioch Bridge and at Mallard Slough so that industries with dual water supply systems drawing from both the river and the Contra Costa Canal, will be able to use river water a lesser proportion of the time to satisfy their high-quality requirements. Since water from the canal is more expensive than water from the river, the result will be increased costs to industry. We estimate this increase in the cost of high-quality water to amount to $19,800 in 1969, increasing to $472,000 per year by 1995.

accomplished, we have grave doubts as to the wisdom of discharging the drain into the San Joaquin River or any part of the San Francisco Bay system as serious deterioration of one part of the Bay System such as Suisun Bay will undoubtedly be transmitted by tidal action throughout San Francisco Bay.

13. A study should be undertaken of a comprehensive plan for the discharge of wastes from the entire Central Valley drainage basin, the Bay Area, including Contra Costa County and the discharge from the combined drain. All users of the required drains, including the State and the Federal Government, should contribute their share of the cost based on the quantity and quality of their wastes.

14. Adoption of an interim solution similar to the proposals studied in Reference 1 would provide time for the accumulation of additional data, including a more accurate determination of the quantity and quality of the waste water to be discharged by the drain. This would result in better estimates of the effect on the receiving waters, and would provide time for additional research on the effect of nutrients and pesticides.

15. In the past major estuaries of the Eastern United States have become grossly polluted before remedial measures have been undertaken. An opportunity exists here to avoid such an undesirable development by foresight and careful planning.

TABLE 32

ESTIMATED ADDITIONAL COSTS TO INDUSTRIES AND CONTRA COSTA COUNTY DUE TO THE EFFECTS OF THE PROPOSED DRAIN

Effect of Drain on	Year 1969	Year 1975	Year 1995
Loss of Assimilative Capacity	$ 00	$1,500,000	$2,300,000
Additional Cost of Industrial Water	19,800	121,000	472,000
Additional Cost of Municipal Water	3,600	13,800	50,500
TOTAL	$23,400	$1,634,800	$2,822,500
ROUNDED TOTAL	$23,400	$1,635,000	$2,823,000

Note: In addition, we estimate that the cumulative annual value of the loss in use of the recreational facilities of the Delta due to the effects of the drain may amount to 50 to 100 million dollars to Contra Costa County by the year 2020.

No.	Title or Description
11	Report on Investigation Fish Kills in Lower Mississippi River, Atchalalaya River, and Gulf of Mexico, U.S. Public Health Service (April 6, 1964).
12	Use of Pesticides, a Report of the President's Science Advisory Committee, the White House (May 15, 1963).
13	Interagency Coordination in Environmental Hazards (Pesticides), Hearings before the Subcommittee on Reorganization and Internal Organizations of the Committee on Government Operations, United States Senate, May 16, 22, 23; June 4, 25, 1963.
14	McCarty, J. C., Statement of PHS Interest in the Disposal of San Joaquin Valley Drainage, Presented to the Interagency Advisory Group (December 16, 1963).
15	An Evaluation of the Economic Benefits Derived from the Improvement of Water Quality in Contra Costa Canal, U. S. Public Health Service Report (June 30, 1962).
16	Wilkinson, L., "Nitrogen Transformation in a Polluted Estuary," Int. Jour. of Air and Water Poll., 7, 737-752 (1963).
17	Galtsoff, P.S., "Environmental Requirements of Oysters in Relation to Pollution," Biological Problems in Water Pollution, Tech. Report W60-3, U. S. Public Health Service (1960).
18	Walker, B. W., "The Ecology of the Salton Sea, California, in Relation to the Sportfishing," California Department of Fish and Game, Fish Bulletin No. 113 (1961).
19	Henderson, C., Q.H. Pickering, and C. M. Tarzwell, "The Relative Toxicity of Ten Chlorinated Hydrocarbon Insecticides to Four Species of Fish," Trans. Amer. Fish. Soc., 88, 23-32 (1959).
20	Hearings before the H. R. Subcommittee on Fisheries and Wildlife Conservation, Serial No. 88-8, June 18 and 19, 1963.
21	Kallman, B. J., Cope, O. B., and Navane, R. J., "Distribution and Detoxication of Toxaphene in Clayton Lake, New Mexico," Trans. of the American Fisheries Society, 91, 14-22 (1962).
22	California Departments of Fish and Game, Public Health, and Water Resources, Minutes of Conference on Agricultural Drainage Treatment, April 11, 1963.

No.	Title or Description
34	Hull, C.H.J., Photosynthetic Oxygenation of a Polluted Estuary, Paper No. 35, International Conference on Water Pollution Research, London, September 1962.
35.	San Luis Interceptor Drain - Economic Considerations - Public Health Service Memorandum dated April 22, 1964, Water Supply and Pollution Control, Region IX, San Francisco.
36.	McKee, J. E., and Wolf, H. W., Water Quality Criteria, Report prepared for the State Water Quality Control Board, Sacramento, California (1963).
37.	Katz, M., and Chadwick, G. G., "Toxicity of Endrin to Some Pacific Northwest Fishes," Trans. Amer. Fisheries Soc., 90, 394-397 (1961).